

FILE COPY

FOREST INSECT LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

453.2
#60.6

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

Project h-1-1.1

Date

Author

TITLE

RESULTS OF PRELIMINARY STUDIES
CONCERNING THE CONDITION OF BEETLE
SUSCEPTIBLE PONDEROSA PINES

By

W. D. Bedard
Associate Entomologist
Bureau of Entomology and Plant Quarantine
March 24, 1941

Forest Insect Laboratory
445 U. S. Court House
Portland, Oregon

JMM
MLL
WLB
JEP
CHS
HLM
AGT
JWB
CBE
RCH
JBY
STC
PCJ
ESS
02

SUBJECT-

INDEX No.-

RESULTS OF PRELIMINARY STUDIES
CONCERNING THE CONDITION OF BEETLE
SUSCEPTIBLE PONDEROSA PINES
Line Project h-1-1.1

Approved by:

F. P. Keen

Senior Entomologist, in Charge

Submitted by:

H. D. Behnd

Associate Entomologist

Forest Insect Laboratory
445 U. S. Court House
Portland, Oregon
March 24, 1941

Contents

	<u>page</u>
Introduction.....	1
Characters Associated with High Risk.....	2
Crown characters.....	2
Other anatomical characters.....	4
Origin and Cause of High Risk Characters.....	6
General consideration of causes.....	6
Analysis of trees showing high risk characters.....	10
General conclusions as to cause.....	14
Relative Mortality Associated with High Risk Characters.....	15
Summary.....	17

RESULTS OF PRELIMINARY STUDIES CONCERNING THE CONDITION OF BEETLE-SUSCEPTIBLE PONDEROSA PINES

Increasing interest by foresters and timber owners in selective logging as a means of bark beetle control has focused attention on determining the current health of ponderosa pines and their immediate chances of death due to pine beetle attack. A great deal of work on this subject was done by the Berkeley laboratory, and Salman and Bongberg^{1/} developed a system using four broad risk classes to indicate current health on the basis of crown deterioration characters. This work showed a definite relationship between the tree health characters used and beetle susceptibility, but the significance of and weight to be given to the various risk characters was not established. This lack of precise definition of characters permits, and in fact encourages, personal judgment to influence risk determinations. Often risk characters, such as dying twigs, differ only slightly or not at all between high and low risk trees. In order to put the diagnosis of tree health on the soundest possible basis, more specific information was needed on the meaning of various risk characters, and their relative importance.

Therefore, a study was outlined to follow up the work of the Berkeley laboratory in order to determine wherein beetle-susceptible ponderosa pines differ from healthy trees, the underlying causes of susceptibility and the external symptoms indicative of high risk. The general plan of the study included three major points. First, determine the characters found in high risk trees which are not found in healthy trees. Second, analyze these high risk characters to determine their origin and cause. Third, determine which characters are indicative of beetle-susceptibility and presage the ultimate death of the tree.

The practical tests of control through logging made by the Weyerhaeuser Timber Company near Bly, Oregon, offered an opportunity for the execution of this study by providing a large number of high risk trees which could be analyzed in detail. Accordingly, a series of high risk trees from the Bly experimental area and a series of normal trees from a regular logging project, also near Bly, were utilized. The method of examination comprised a preliminary observation immediately before the tree was felled, and a final study after it had reached the ground. In the preliminary examination, records were made of the tree

^{1/}Bongberg, J. W. Tree susceptibility studies on Black's Mountain Experimental Forest. A progress report. Unpublished report Berkeley Forest Insect Laboratory. Feb. 26, 1938.

class; risk class; shape, density and general appearance of the crown; and length (short, normal, long) and complement (small, average, heavy) of foliage. After felling, the bole was examined at several points for cortical and subcortical insects, rot and injury. These data were recorded for base, mid-bole and top. Length and complement of foliage were measured and recorded for top and bottom of the crown. Bark thickness and depth of cracks, width of active sapwood, cambium moisture and a general ring growth pattern were also recorded.

Characters Associated with High Risk

The first step in carrying out the plan of this study was to compare the high risk trees with the normal trees to determine what characters they have in common and wherein they differ. Such a comparison is based on the assumption that the trees marked on the experimental area were actually high risk trees. It is believed that on the average this assumption is sound because the trees were marked according to the best available data from the work of both the California and Portland laboratories. In addition, 4.7 percent of the marked trees which were examined had been attacked by Dendroctonus brevicornis subsequent to the marking.

Crown Characters

Table 1 presents the comparison of these two series of trees on the basis of crown characters, and a determination of significant differences through the use of the chi square test.

Eleven significant crown differences between the normal and high risk trees are noted in table 1. These are principally differences in crown density, although two differences occur in needle condition and two in crown injury. Crown density shows that 84 percent of the crowns on normal or healthy trees fall in the first four groups comprising crowns designated as dense, normal, normal with some open spots, and normal crowns in the top but open below. The latter class appears to be a perfectly normal crown found on long clean-boled trees with short vigorous crowns. Approximately 70 percent of the high risk crowns fall in the next three groups comprising crowns characterized as scraggly, thin open top, or very thin and open throughout. In general then, normal trees have normal or better crowns and high risk trees have sub-normal crown densities.

Table 1—Comparison of normal and high risk trees on basis of crown characters.

Crown character	Normal (69 trees)		High risk (271 trees)		Significance of difference ^{a/}
	No. trees	Percent	No. trees	Percent	
Dense crown	2	2.9	0	0	s*
Normal density crown	13	18.8	18	6.6	h*
Normal density crown. Some open spots	29	42.1	45	16.6	h*
Normal crown in top. Open below	14	20.3	17	6.3	h*
Scraggly scattered open crown	8	11.6	123	45.4	h**
Open thin crown in top. Normal or dense below	3	4.3	50	18.5	s**
Very thin open crown	0	0	18	6.6	s**
Heavy complement long coarse needles	30	44.1	14	5.1	h*
Average complement long needles	3	4.4	10	3.7	n
Heavy complement normal needles	4	5.9	10	3.7	n
Average complement normal or moderately short needles	15	22.1	69	25.3	n
Weakness in top. Slightly shorter needles or smaller complement	11	16.2	65	23.8	n
Small comp. normal to med. short needles	2	2.9	12	4.4	n
Small complement normal to mod. short light weight needles	0	0	1	0.4	n
Average or small complement very short needles in top	3	4.4	84	30.8	h**
Small complement very short needles throughout	0	0	8	2.8	n
No crown injury or weakness	35	52.2	16	5.9	h*
Witch's broom	0	0	2	0.7	n
Spike or broken top not active	3	4.5	20	7.4	n
Abundant dead or dying branches	9	13.4	37	13.6	n
Weak spots in crown below top	16	23.9	64	23.5	n
Weak top	0	0	10	3.7	n
Dying tip of terminal	1	1.5	10	3.7	n
New active spike, broken top or new dying area below old spike	0	0	90	33.0	h**
Bunched foliage	2	3.0	20	7.4	n
Fading or off-color crown	1	1.5	3	1.1	n
Few dead or dying branches	4	5.9	46	16.9	n
Faded or fading twigs	20	29.4	84	30.9	n
Few dead or dying branches and twigs	3	4.4	31	11.4	n

^{a/}Significance determined by chi squares. h=difference highly significant
s=difference significant
n=no significant difference

*indicative of normality
** " " high risk

Needle condition shows a less definite relationship. However, two highly significant differences are apparent. Healthy crowns show a difference in having a heavy complement of long coarse needles, while high risk crowns exhibit a difference in the very short needle character in the top of the crown. Other needle conditions are as likely to be found in one group as the other, although the tendency is for healthy crowns to possess normal or better foliage and high risk crowns to have normal or sub-normal foliage.

Crown injury or weakness also shows two significant differences. Normal trees tend to have no crown weakness, or when present, it is inactive. High risk crowns, on the other hand, usually exhibit some weakness, the most common one being a new active spike, new broken top or new dying area below an old spike.

We may conclude from this analysis that the important crown characters associated with high risk are: (1) New spike, newly broken top or an active area below an old spike. (2) Scraggly, scattered open crown. (3) Very short needles in top of crown with normal or long needles below. (4) Open thin crown in top. (5) Open thin crown throughout.

Other Anatomical Characters

Immediately after the tree had been felled, it was examined in detail to ascertain, in so far as possible, other characters which might distinguish high risk trees from normal trees, or which might give some clue as to the cause of low vigor. Three anatomical and one physiological character were recorded in this portion of the study. Bark thickness and width of active sapwood were measured on the stump, the relative widths of approximately the last 50 annual rings were also determined from the stump with the aid of a hand lens, and cambium moisture was determined at several points along the tree bole. Complete records were not taken on all trees examined, but those available are shown in table 2.

Table 2—Comparison of normal and high risk trees according to other anatomical characters

		Normal (40 trees)		High risk (148 trees)		Significance ^{a/} of Difference
Character		No. trees with character	Percent of total	No. trees with character	Percent of total	
Bark thickness	thick	14	35.0	47	31.8	n
	medium thick	16	40.0	60	40.5	n
	thin	10	25.0	41	27.7	n
Width active sapwood	wide	23	57.5	46	31.2	s*
	medium wide	13	32.5	83	56.0	n
	narrow	4	10.0	19	12.8	n
Cambium moisture	wet	23	57.5	81	54.8	n
	moist	9	22.5	29	19.6	n
	dry	8	20.0	38	25.6	n
General growth pattern	slow—steady	4	10.0	19	12.8	n
	slow with decline between: '21-'35. Recovery since					
	'38	2	5.0	6	4.0	n
	slow with decline between: '21-'35. No recovery	0	0	24	16.3	s**
	fair—steady	8	20.0	3	2.0	h*
	fair with decline between: '21-'35. Recovery since					
	'38	10	25.0	6	4.0	h*
	fair with decline between: '21-'35. No recovery	0	0	33	22.4	h**
	good—steady	10	25.0	4	2.7	h*
	good with decline between: '21-'35. Recovery since					
	'38	6	15.0	6	4.0	s*
	good with decline between: '21-'35. No recovery	0	0	47	31.8	h**

^{a/}Significance determined by chi squares. h = difference highly significant
s = difference significant
n = no significant difference

*Indicative of normality
** " " high risk

In table 2, significant differences are apparent in width of active sapwood and in general growth pattern. Healthy trees tend to have a wide sapwood, while in high risk trees, the sapwood tends to be medium wide, or narrow. The greatest significant difference is found in growth. In healthy trees, growth is steady or, when declines do occur during poor growth periods, recovery is apparent when growth conditions improve. High risk trees, however, usually show declines from which no recovery is apparent. Both active sapwood and growth are of course modified by age.

In summation, the characters associated with weakened trees are: (1) Scraggly, scattered, open crown, (2) thin open top, normal or dense below, (3) very thin, open crown throughout, (4) very short needles in top of crown, normal below, (5) new spike, newly broken top or active area below an old spike, (6) medium wide active sapwood, and (7) abrupt growth declines with no recovery.

Origin and Cause of High Risk Characters

In order to determine the origin and cause of those characters definitely associated with high risk, each one will be analyzed separately. Since individual symptoms cannot be isolated and studied without regard to other tree conditions, it will also be necessary to consider the relationship of each to other characters. Before proceeding with these individual analyses, however, some general consideration will be given to the few, more obvious, possible causes of tree decline in order to eliminate those which are found proportionately in normal and high risk trees.

General Consideration of Causes

Possible causes of tree decline have been divided into four general classes in this study, namely: Insects, diseases and injuries, physiological and nutritional disturbances, and weather. Actually these may be, and probably are interrelated. However, for the purpose of study and comparison to determine their relative sequence and importance, they have been considered separately.

Numerous insects were found associated with the weakened trees, and a few species were found commonly in the normal group. Specific determinations are not available for all, because a considerable amount of material is yet in rearing. A partial list is as follows:

Dendroctonus valens was found at the base of a few of the high risk trees. Indications within the area examined are that the standing green trees attacked by this insect usually show one or more high risk characters. An interesting case was observed by Keen and the writer while marking high risk trees in a lightly burned area. Within the limits of the burn, it was noted that D. valens had attacked only high risk trees regardless of the severity of the burn.

Pityophthorus spp. were found in dying twigs and small lateral branches on a few of the high risk trees. No evidence was secured as to whether insect attack caused the dying branches or whether attack followed a natural sloughing as a result of readjustment by the tree between roots and crown. However, the absence of these insects in the majority of dying twigs and branches indicates that their attack is secondary.

Ips latidens was associated with Pityophthorus in some of the small dying branches and was also found in larger dying lateral branches as well as in new spikes and new dying areas below old spikes. It was impossible to tell from records obtained in 1940 whether this insect was acting in a primary capacity or whether it was the final factor in a chain of events which caused the death of these branches.

Ips oregoni was found in new spikes, new dying areas below old spikes and in large dying lateral branches. It was sometimes found with I. latidens and sometimes with I. emarginatus. Like other species of Ips, the actual recognition of the species involved depended on finding the insects actively present, which was possible only when attack had occurred during the 1940 season. This was found in only four cases. Evidence of Ips attack was found in seven additional cases and undoubtedly occurred in others, but had been obliterated by abundant cerambycid work. Hence, with so few cases, it was impossible to tell whether death was actually caused by these insects.

Dicerca sp. larvae were found in the outer bark of slightly more than half of the high risk trees and slightly less than half of the normal trees. These larvae were more frequently found in the top than the base of the tree and were most abundant in trees with thick or fairly thick flat bark. This apparently preferred bark condition occurs most frequently on class 4C, 4B and 3C trees and it was in the bark of these trees that bark flatheads were most commonly found. They were also found in the bark of trees in other classes, but occurred infrequently in class 2 trees and rarely in class 1. These bark flatheads sometimes barely touch the current phloem tissue causing a slight pitch pocket. Other than this slight scarring, they apparently were doing no damage; hence, no importance is attached to their presence.

Melanophila californica was found in the incipient stage, usually with no other insect associates except Dicerca which was in the outer bark. M. californica was also found in the fast growing stage in and adjacent to new dying areas, with the incipient stage sometimes absent. Although this insect contributes to the general tree decline by hindering water conduction, as pointed out by the Berkeley laboratory, the evidence in this study does not indicate that it is the primary cause of this decline owing to its absence in more than half of the high risk trees examined.

Melanophila gentilis (thought to be this species because of its location in the phloem) was found in the fast growing stage in current year's phloem adjacent to new dying areas.

Anthaxia (?) sp. Two cases were observed of an unknown tiny flathead larva making sharply zig-zagged galleries in the current growth of leaders less than one inch in diameter. No generic determination could be made from Burke's key, the larvae approaching closely to Anthaxia but lacking the ambulatory tubercles of this group.

Monochamus spp., Stenocorus lineatum and Graphisurus sp. were commonly found associated in new spikes, dying areas below old spikes and occasionally in large dying lateral branches. These three genera were so badly mixed in all cases examined as to make it impossible to tell much about them.

Matsucoccus sp. was found commonly in various stages on the foliage and twigs of both normal and high risk trees. In attempting to determine the cause for twig and small branch mortality, it was found that only 28 percent of 70 cases could logically be attributed to this insect.

Two diseases and one injury were also recorded in this study. Mistletoe was so common in both areas that its presence was recorded only when sufficiently abundant to deform limbs. Heart rot and fire scars were noted when present.

In table 3, the normal and high risk trees are compared on the basis of these insect, fungus and bole injury indicators.

Table 3—Comparison of normal and high risk trees on basis of insects, fungi and injuries.

Insect, fungus, or injury	Normal (69 trees)		High risk (271 trees)		Significance ^{a/} of difference
	No. trees containing	Percent of total	No. trees containing	Percent of total	
No insects, fungi or injuries	35	51.4	35	12.9	h*
<u>Dendroctonus brevicornis</u> and <u>valens</u>	0	0	20	7.3	s**
Melanophila	0	0	112	41.2	h**
Dicera	30	41.8	166	61.0	n
Ips spp. Pityophthorus spp.	0	0	11	4.1	n
Matsucoccus sp.	6	8.8	18	6.6	n
Curculionidae	0	0	26	9.6	s**
Mistletoe	2	2.9	31	11.4	n
Heart rot	7	10.3	47	17.3	n
Fire scar	6	8.8	59	21.7	s**

^{a/}Significance determined by chi squares. h = difference highly significant.
s = difference significant
n = no significant difference

* Indicative of normality
** " " high risk

Five significant differences are shown by table 3. Healthy trees are predominantly free of insect, fungus and bole injury. High risk trees differ from normal trees in that fire scars, Dendroctonus, Melanophila, and cerambycids are frequently found in them. It is obviously to be expected that healthy trees would be free from harmful agents and that Dendroctonus brevicornis would be associated with high risk. However, the association of Melanophila, cerambycids and fire scars with high risk points to the conclusion that if they are not the causes of tree decline they may at least serve as one of the indicators of high risk. Table 3 also shows that the bark flathead Dicerca, Latesuccus, Ips, Pityophthorus, mistletoe and heart rot are proportionately abundant in both groups and show no significant differences as to occurrence in either group.

Analysis of trees Showing High Risk Characters

In the preceding discussion it was shown that certain crown characters and certain anatomical characters indicative of poor vigor are definitely associated with high risk trees. It was also shown that certain insects and one injury are similarly associated with high risk trees. What then can be concluded from these data? Are any of the insects, or the injury, the cause of these high risk crown characters? Are any of the insects, other anatomical characters, or the injury a clue to the possible cause of high risk?

In table 4, these associated factors are compared according to the various high risk crown characters and combinations of them. In this table, the significance of differences in each factor was determined by comparing the occurrence of each with the mean for all trees showing high risk characters.

Table 4—Condition of trees with high risk crown characters as shown by insects, injury, growth and sapwood.

Characters	Percentage of trees with																			
	Db or Dv		Melan-	Ceram-	Fire	Steady	Growth	Growth		Wide	Medium	Normal								
	Signif-		ophila	bycids	Scar	growth	decline &	decline no		sap.	sap.	sap.								
	icance						recovery	recovery												
	of	Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.		Sig.
	% Diff. ^{a/}	% Diff.	%	% Diff.	%	% Diff.	%	% Diff.	%	% Diff.	%	% Diff.	%	% Diff.	%	% Diff.	%	% Diff.	%	% Diff.
(1) Thin open crown in top	7.6	n	37.7	n	22.6	s	24.5	n	19.2	n	15.3	s	65.5	h	30.8	n	53.8	n	15.4	n
(2) Short needles in top	9.0	n	55.7	n	11.4	n	14.8	n	7.4	s	3.8	n	88.8	h	31.4	n	52.9	n	15.7	n
(3) Thin open crown	6.0	n	60.0	s	6.0	n	22.2	n	25.0	n	25.0	h	50.0	h	12.5	h	75.0	s	12.5	n
(4) New spike etc.	8.6	n	55.4	n	23.9	s	22.8	n	9.6	n	11.5	n	78.9	h	30.0	n	52.0	n	18.0	n
(5) Scraggly crown	5.9	n	40.4	n	5.1	n	20.6	n	15.7	n	12.9	n	71.4	h	30.3	n	54.5	n	15.2	n
Combination 1, 3 or 5 + 4	8.7	n	87.5	h	30.0	h	25.0	n	0.0	h	8.7	n	91.3	h	19.3	h	57.9	n	22.8	s
Combination 1, 3 or 5 + 2 + 4	11.2	n	89.0	h	31.6	h	22.2	n	0.0	h	0.0	n	100.0	h	18.0	h	53.4	n	28.6	h
Combination 1, 3 or 5 + 2	9.1	n	90.9	h	9.1	n	24.2	n	0.0	h	11.2	n	88.8	h	17.1	h	52.3	n	30.6	h
Combination 2 + 4	20.0	n	80.0	h	80.0	h	20.0	n	0.0	h	0.0	n	100.0	h	0.0	h	100.0	h	0.0	h
Mean all high risk	7.3		41.2		9.6		21.7		17.5		12.0		70.5		31.2		56.0		12.8	

^{a/}Chi squares used to determine significance of difference between mean for high risk character and mean for all trees showing high risk characters.

h = difference highly significant
s = difference significant
n = no significant difference

Table 4 is most readily studied by dividing it into two parts, considering the single crown characters separately from their various combinations. This is advisable because certain duplications of trees in the upper portion of the table, necessary to segregate single characters, were eliminated from the lower portion by combination, as were other trees showing but a single high risk crown character. Hence, the combinations, although based on the same series, are actually represented by fewer trees than the single characters. As a result, it is apparent that trees with combinations of high risk crown characters represent a different set of conditions in that they bring out the importance of certain factors by showing significant differences which are not apparent when only single characters are considered.

It is natural to expect that trees with two or more major high risk symptoms would be in a more critical condition than trees with only one such symptom. This is the interpretation placed on the differences shown between the two portions of table 4 because of the increased infestation by Melanophila, the tendency toward narrow sapwood, the complete lack of trees with steady growth and an increased number with no growth recovery following decline. These general growth and sapwood characters appear to indicate a general tree decline which permitted the increased infestation by Melanophila.

Concerning the other factors, three of the four combinations show significant differences in the percentages of trees containing cerambycids. This is explained by the fact that where these differences occur, the combination includes a new active spike, and since cerambycids are associated with this character they show increases in association with it. Hence, these data indicate that cerambycids are not important in tree decline and are not satisfactory indicators of high risk because of their association with only one character.

No significant differences are apparent in the percentages of trees infested with Dendroctonus. However, D. brevicornis is undoubtedly the ultimate cause of tree mortality and for this reason no great difference would be expected in only one year's record, nor would it be possible to consider Db. as a possible indicator of high risk. If, however, mortality records according to crown symptoms were available over a period of years, it would be logical to expect that significant differences might be shown in the relative susceptibility of trees showing different symptoms.

Although fire scars are associated with high risk crowns, no significant differences are shown in the mean percentages in table 4. Hence, they do not appear to be definitely connected with any one type of high risk crown, nor are they sufficiently abundant to indicate that fire damage to the tree is the cause of tree decline. It is possible, however, since fire appears to be associated with high risk, that the indirect effect of fire may be one of the factors causing tree decline.

The portion of the table dealing with single crown characters shows comparatively few significant differences in the mean percentages. One outstanding exception is shown by general growth patterns. Here again the tendency is toward poor growth with no recovery following decline. Two exceptions occur in the thin open crowns, and the thin open in the top, both of which appear to be making somewhat improved growth over the general mean. Although unexpected, growth improvement in these two tree types is entirely possible. For example, assume the progression toward a scraggly-crowned tree to go through the following stages: (1) A general sloughing of twigs and needles in the top of the crown to produce a thin open top. (2) A more vigorous sloughing of twigs and needles to produce a thin open crown throughout. (3) A shortening of the needles in the crown. (4) A sloughing of the top of the crown to cause a spike. (5) A sloughing of the larger branches to produce a scraggly crown. This assumption is not too far-fetched because on the basis of physiology, these are but natural defenses of the tree to resist unfavorable environmental conditions. If the first or second attempt at defense is successful, it is logical that some improvement in growth would follow. On the other hand, if more drastic defenses are necessary, the tree probably reaches a point from which recovery is impossible. This, of course, is pure theory, used entirely to point out that growth improvement in high risk trees is not beyond expectation.

*What
Character
Growth*

Among the other factors it will be noted that cerambycids show a significant difference not only in new spikes, but also in crowns thin and open in the top. The explanation of this lies in the fact that many trees with a newly formed spike fall into this crown classification so that the association of cerambycids with spikes causes the comparatively high percentage of these insects in this crown type.

*Ceram
Crown*

General Conclusions as to Cause of High Risk Characters

Insects: Although certain insects, not present in normal trees, occur commonly in high risk trees, they are not found in a sufficient number of cases, either singly or in combination, to be the primary cause of the symptoms associated with high risk. In addition, when the current nature of the insect work recorded in these examinations is considered in conjunction with the general tree decline indicated by the narrowed sapwood and abrupt growth decline which occurred from five to fifteen years ago, it is logical to reason that the insects followed some type of physiological deterioration. However, the evidence points to the fact that active insect work (excepting D. brevicornis) may be a good index of tree vigor because of its greater abundance when high risk crown characters are combined.

Diseases and injuries: No significant differences between normal and high risk trees were found in the diseases recorded in this study. However, additional work is planned on this phase, particularly in regard to root fungi.

One significant difference in injury was recorded. Fire scars were more abundant on high risk trees than on normal trees, but were not definitely associated with any one symptom or combination of symptoms. Neither were they found in sufficient numbers to be the primary cause of the general tree decline. However, their definite association with high risk trees is not to be overlooked as a possible clue to the cause of tree decline.

Physiological and nutritional: The narrowed sapwood and growth patterns indicating abrupt physiological disturbances are strong evidence that the cause of high risk might be found in this phase of the study. No other data are available, but additional work is planned for this phase of the study.

Weather: The sapwood and growth pattern characters mentioned in the previous section are equally strong evidence that weather might be the initial cause of tree decline.

Relative Mortality Associated with High Risk Characters

The actual mortality associated with these various high risk characters and combinations of them is the third objective of this study. No work was planned or conducted on this phase, but a few data are available for analysis from 30 permanent 10-acre plots which were established in 1938 and 1939 throughout the pine stands of eastern Oregon to study tree-class characteristics indicative of beetle hazard and ponderosa pine mortality rates. Detailed tree descriptions were recorded when these plots were established, so that by going over the records it was possible in most cases to determine whether or not the tree showed one or more of the important high risk characters. In a few cases, this was difficult to accomplish so that some inaccuracies are probably present in that portion of table 5. Since two and in some cases only one year's tree mortality records are available on these plots, only seven of them contained such records. Hence, the data from these seven plots are all that were used in the summary shown in table 5.

In addition to these 10-acre plot data, there are also the 1940 tree mortalities which occurred among the 340 trees examined in this study on the Bly experimental area and nearby logging area. These are also shown in table 5.

In table 5, a mortality ratio was computed for each crown character in order to determine its relative weight. Because of the unequal number of living and dead trees in each character group, these ratios were based on percentages in order to put them on a comparable basis. The ratio of dead to living was computed by dividing the percent of the total dead within any given group by the percent of the total living in the same group.

It should also be noted that duplications occur throughout the table because of segregating trees by single characters and also including them in combinations of characters. Hence, the total number of trees used in compiling this table does not check with the total of the vertical column.

Table 5—Mortality associated with high risk characters

Character	10-acre plots				Bly data				Total			Mortality Ratio
	No. trees	No. dead	% dead		No. trees	No. dead	% dead		No. trees	No. dead	% dead	
No weakness	1197	7	0.6	:	61	0	0.0	:	1258	7	0.5	0.23
(1) Thin open crown in top	197	1	0.5	:	50	2	4.0	:	247	3	1.2	0.51
(2) Short needles in top	271	6	2.2	:	84	5	6.0	:	355	11	3.1	1.35
(3) Thin open crown	163	5	3.1	:	18	1	5.6	:	181	6	3.3	1.45
(4) New spike, etc.	84	3	3.6	:	90	3	3.3	:	174	6	3.4	1.50
(5) Scraggly crowns	121	4	3.3	:	123	5	4.1	:	244	9	3.7	1.62
Combination 1, 3 or 5 + 4	76	3	3.9	:	80	4	5.0	:	156	7	4.5	1.98
Combination 1, 3 or 5 + 2 + 4	90	4	4.4	:	36	2	5.6	:	126	6	4.8	2.09
Combination 1, 3 or 5 + 2	163	8	5.1	:	66	4	6.0	:	229	12	5.2	2.33
Combination 2 + 4	11	1	9.1	:	5	1	20.0	:	16	2	12.5	6.04
Total number trees involved in compiling table	2285	23	1.0	:	340	13	3.8	:	2625	36	1.4	

Little can be concluded from the data shown in this table because of the short period during which records were obtained. However, it appears that among the trees included in table 5, mortality is associated with high risk characters and that combinations of these characters indicate a greater susceptibility to Db. attack. No significant difference is apparent in the amount of mortality associated with each character so that no conclusion can be reached concerning the relative importance of each in indicating susceptibility.

Summary

This report deals with an analysis of data secured from examination of a series of high risk trees on the Bly beetle control logging project and a series of normal trees on a regular logging operation also near Bly, Oregon. The object of the study was to determine wherein beetle-susceptible ponderosa pines differ from healthy trees, the underlying causes of susceptibility and the external symptoms indicative of high risk.

Seven characters were found to be associated with the high risk trees. These were: (1) Scraggly, scattered, open crown, (2) thin open top, normal or dense below, (3) very thin open crown throughout, (4) very short needles in top of crown, normal below, (5) new spike, newly broken top or active area below an old spike, (6) medium wide active sapwood, and (7) abrupt growth declines with no recovery.

In analyzing these characters as to their origin and cause, it was found that Dendroctonus, Melanophila, cerambycids and fire scars were found frequently in high risk trees, but not in normal trees. However, these factors were not in sufficient numbers, either singly or in combination, to be the primary cause of tree decline.

The narrowed sapwood and general growth patterns of high risk trees were believed to indicate a general decline in tree vigor resulting from a more general cause such as weather or soil.

Very little data are available concerning the relative mortality associated with the symptoms of high risk. Those available indicate that mortality appears to be associated with the high risk characters and that combinations of these characters indicate a greater susceptibility to insect attack.